DOCUMENT RESUME

ED 394 817 SE 058 261

AUTHOR Hammrich, Penny L.; Blouch, Kathleen K.
TITLE Elementary Teacher Candidates' Conceptions of the Nature of Science and Science Teaching.
SPONS AGENCY National Science Foundation, Arlington, VA.
PUB DATE 28 Mar 96
CONTRACT NSF-33-1802301
NOTE 28p.; Paper presented at the Annual Meeting of the National Science Teachers Association (St. Louis, MO, March 28, 1996).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Elementary Education; Elementary School Science; *Elementary School Teachers; Interviews; Knowledge Base for Teaching; *Methods Courses; *Preservice Teacher Education; Questionnaires; *Science Instruction
IDENTIFIERS *Nature of Science

ABSTRACT

This study attempted to explore the relationship between elementary teacher candidates' conceptions of the nature of science and their consequent conceptions of teaching science. In order to measure patterns and trends in how elementary teacher candidates define the nature of science and the teaching of science, an open-ended qualitative questionnaire and follow-up interviews were administered to 47 elementary teacher candidates prior to and after the completion of a science methods course. Results indicated that few of the candidates had considered their ideas about the nature of science. In general, answers represented views of school science rather than science as practiced by scientists. Responses also indicated that the teacher candidates had developed their conception by what they had learned in past science classes or in textbooks and not from personal involvement and experience with the practice of science. After participating in the methods course, three-fourths of the teacher candidates described the nature of science as the process of discovery and saw science concepts as relative and subject to personal construction of meaning. Moreover, the candidates recognized that learning is an active process and is a construction of individual understanding and that their role should be to facilitate personal construction. Contains 53 references. (JRH)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY
P. Hammrich
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

ED 394 817

Elementary Teacher Candidates' Conceptions of the Nature of Science and Science Teaching

Penny L. Hammrich
Temple University
and
Kathleen K. Blouch
Millersville University

Running head: ELEMENTARY TEACHER CANDIDATES'

This material is based upon work supported in part by a grant from the National Science Foundation (Grant No. 33-1802301). Any opinions, findings, conclusions, and/or recommendations expressed in this article are those of the authors and do not necesssarily reflect those of NSF.

A paper presentation at the 1996 Annual Meeting of the National Science Teachers Association, St. Louis

BEST COPY AVAILABLE

Elementary Teacher Candidates' Conceptions of the Nature of Science and Science Teaching

Penny L. Hammrich, Temple University

Kathleen K. Blouch, Millersville University

By the time elementary teacher candidates enter a science methods course, they have been exposed to a substantial amount of science content. Generally, less attention will have been paid to the nature of science and the teaching of science itself. The nature of science being how science proceeds, how the scientific community decides what to accept and reject, and how much faith there is in a large body of scientific knowledge and beliefs which are continuously developing. The teaching of science being how scientific knowledge is communicated, how scientific knowledge is constructed, and how teachers facilitate instruction for understanding. Yet, understanding the substance of science without understanding its construction and limitations and consequently how to communicate scientific knowledge must be considered.

Science educators have not reached a consensus concerning the specific content or method of instruction to be included in a science methods course (Lederman, 1992). However, there is an agreement that science instruction should facilitate the development of an "adequate understanding of the nature of science" or an understanding of "science as a way of knowing" (American Association for the Advancement of Science, 1989; Hazen & Trefil, 1991; Rutherford & Ahlgren, 1990). The nature of science has been defined in many ways throughout the decades dating back to its earliest inception in the report of the Central Association of Science and Mathematics Teachers (1907) which emphasized the scientific method and the processes of science. Most recently the nature of science has been defined as an individual's beliefs and

DRAFT - do not quote or cite

values inherent to his/her development of scientific knowledge (Lederman & Zeidler, 1987). Indeed, science educators have been adamant in their advocacy of student's understanding of the nature of science (Kimball, 1968). Sauders (1955) described the nature of science as the most important aspect of science teaching.

How well do teacher candidates understand the nature of science and the teaching of science? This is not an idle question nor is it a new one. Over the last three decades, a number of researchers have used instruments such as the *Test on Understanding Science* (Klopfer & Cooley, 1961), the *Nature of Science Scale* (Kimball, 1965), and the *Nature of Scientific Knowledge Scale* (Rubba & Anderson, 1978) in an attempt to determine what students understand about the nature of scientific knowledge. There have also been a number of studies that investigated the relationship between teachers conceptions of the nature of science and teachers conceptions of the teaching of science (Brickhouse, 1989, 1990; Duschl & Wright, 1989; Lederman 1986a; Lederman & Druger, 1985; Lederman & Zeidler, 1987; Zeidler & Lederman, 1989). Despite these efforts, researchers have not established a generally accepted view of how teacher candidates' conceptions of the nature of science influence their conceptions of teaching science such as how to design, structure, and present science. More specifically, research on teachers' conceptions has been largely directed at the secondary and university level.

This study attempted to explore the relationship between elementary teacher candidates' conceptions of the nature of science and their consequent conceptions of teaching science. It is important to elaborate that past research has led to the following: (a) science teachers do not possess adequate conceptions of the nature of science, irrespective of the instrument used to assess understandings; (b) techniques to improve teachers' conceptions have

met with some success when they have included either historical aspects of scientific knowledge or direct attention to the nature of science; (c) academic background variables are not significantly related to teachers' conceptions of the nature of science; and (d) teachers understanding of the nature of science is not fixed and rigid but can and does change. The study followed the assumption that a teacher's understanding of the nature of science affects his/her conceptions of how to design, structure, and present science.

The study reflects the thesis proposed by Munby (1982), namely that researchers tend to assume students attach the same meaning to questions as do the developers of the questions; thereby, students own views remain hidden. One way to get around this problem is to discover students' own understandings in a free-response questionnaire or in an interview setting. In the last decade many science education research studies have been conducted in this manner. Collectively, these studies have added to the knowledge of what students understand about the nature of science and the teaching of science. Yet, while attention has been paid to the relationship between secondary teachers conceptions of the nature of science and their conceptions of how to teach science; few studies have sought to look at how elementary teacher candidates' conceptions of the nature of science influence their conceptions of teaching science. In attempt to address this issue, a qualitative study of elementary teacher candidates' conceptions of the nature of science and thus the impact of such conceptions on their conceptions of teaching science was conducted. Questions centered around elementary teacher candidates' conceptions of the nature of science (what is science), personal construct of teaching science (how they think science should be taught), and facilitation of science knowledge (how we acquire knowledge thus how they view how students learn science). The results of this study add to the body of

literature focused on equating teachers' conceptions of the nature of science with their practice of teaching science.

Science Methods Course

With the recognition that the understanding of the nature of science is a global conception that frames teachers understanding and teaching of science (Bohm & Peat, 1989), the authors sought to develop and implement improvements to the elementary science methods course. The primary focus of the methods course design was to expose and challenge elementary teacher candidates' conceptions of the nature of science. After doing so, to concentrate on fostering conceptual growth of the teacher candidates understanding of teaching science. Forty-seven upper-level elementary education majors at Temple University participated in the newly designed elementary science methods course. The course met for three hours a week for fifteen weeks. Based on recommendations from the literature the following adjustments were made to the design of the elementary science teacher education program at Temple University in Philadelphia, Pennsylvania.

1. The application of cooperative controversy to challenge teacher candidates conceptions of the nature of science (Cohen, 1986;Johnson & Johnson, 1979; Linn & Burbules, 1993; Slavin, 1987).
2. The application of an understanding of the nature of science (Chalmers, 1988; Hodson, 1986; Nadeau & Desautels, 1984;Solomon, Duveen, Scot, & McCarthym, 1992).
3. The application of a constructivists perspective in educating teacher candidates (Baird, Fensham, Gunstone & White, 1991; Brooks & Brooks, 1993; Driver & Oldham, 1986; Fosnot, 1989; Roth, 1990; Shapiro, 1994; Tobin, 1993; Vosniadoe, 1991; Yager, 1991).
4. The application of reflective practice where the teacher candidates

reflect and communicate their conceptions of the nature of science and effective teaching (Calderhead, 1992; Cronin-Jones, 1991; Dewey, 1933; Munby & Russell, 1989; Raizen & Michelsohn, 1994; Russell, 1994; Schon, 1993; Shulman, 1987).

5. The application of an environment that models conceptual change teaching (Anderson, 1987; Driver & Oldham, 1986; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Hewson, Zeichner, Tabachnick, Blomker, & Toolin, 1992).

6. The application of the American Association for the Advancement of science reform initiatives in alignment with the course goals (American Association for the Advancement of Science, 1990, 1993; Raizen & Michelsohn, 1994; Shulman, 1987).

The new elementary education methods course incorporated the above recommendations. Instructional materials included handouts, pertinent readings on the nature of science and the teaching of science, and videos such as "The Private Universe" (Schneps, 1987). Teacher candidates actively participated in discussing and debating their conceptions of the nature of science and science teaching, developing lessons to match grade specific benchmarks, constructing alternative assessment measures, and redesigning and teaching lessons that incorporated alternative teaching strategies to more effectively communicate science content to elementary students.

Method and Analysis

In order to measure patterns and trends in how elementary teacher candidates define the nature of science and the teaching of science an open-ended qualitative questionnaire and follow-up interviews were developed and administered to the elementary teacher candidates prior to and after the completion of the methods course. The questionnaire contained fifteen

questions. The questions were divided into three areas: overall conception of the nature of science, personal construct of the teaching of science, and facilitation of science knowledge. Follow-up interviews were conducted to validate the constructs devised to ensure that they represented the teacher candidates' conceptions as purported by the questionnaire. Teacher candidates were all told that by writing down their conceptions of the nature of science and the teaching of science they would be able to discover and reflect upon their own conceptions. The responses were analyzed by content analysis using the constant comparative method as outlined by Strauss (1987), measuring patterns and trends on how teacher candidates define the nature of science and the teaching of science. Both authors analyzed the responses. One author analyzed the responses twice for an agreement of 87% (intra-rater reliability). The agreement between the two author's analysis was 86% (inter-rater reliability).

Results

Eight broad conceptual categories were identified. The conceptual categories included: (a) school based science - the practice of science; (b) knowledge as fact - knowledge as dynamic; (c) no prior conception - surface conception (novice understanding); (d) no prior conception - reflective conception (experienced understanding); (e) pedagogical knowledge - epistemology; (f) terminal learner - continual learner; (g) external relevancy - internal relevancy; (h) learning as transmission - learning as construction. Results are presented under three main headings, namely overall conceptions of the nature of science, personal construct of the teaching of science, and facilitation of science knowledge.

Overall conception of the nature of science. Under this heading, the following questions were asked: What is the nature of science? How did you

develop your conception of the nature of science? What is a science concept? How did you develop your conception of what is a science concept? What are the three most important concepts for elementary science students to come to understand and why?

Before participating in the science methods course, it was interesting to note that in view of the fact that the elementary teacher candidates were in their last year of college and had taken the required science courses, few appeared to have ever considered the initial question, What is the nature of science? In general, answers represented views of school science rather than science as practiced by scientists. While this is not surprising, it is disturbing as what seems to be represented is a view about the learning of the subject of science rather than its actual practice. A typical response was, "The nature of science is learning about matter, living things, environment and the whole vicious cycle of the world" and "I don't know...I remember reading about the nature of science along time ago." Also it was noted that teacher candidates saw the nature of science as an entity to be learned, some phenomena that they themselves were not apart of. For example, "Science is the study of what is going on and the properties that exist outside oneself."

In response to the question, How did you develop your conception of the nature of science?, overwhelmingly the responses indicated that teacher candidates developed their conception by what they learned in past science classes or in the textbook. A general response was, "I developed my conception by looking back on my experiences in past science classes...teachers gave me their views of science" and "What I saw on television or read in a textbook." Personal involvement and experience with the practice of science was hardly mentioned as a factor that led to their conception of the

nature of science, which suggests that school science presents a distorted view of scientific practices in the real world.

A science concept was seen primarily as a fact, term, or a theory. A general response was, "a science concept is a term, fact, or theory used to describe things like organisms, elements, and properties" or " a science concept is having knowledge of the world." A few of the teacher candidates saw a science concept as an aspect of science such as chemistry, physics, and biology. Teacher candidates hardly ever mentioned that a science concept is constructed individually, which suggests that a science concept represented something to be learned of what already exists.

In response to the question, How did you develop your conception of a science concept?, overwhelmingly the responses indicated past schooling or they had no idea. A typical response was, "Teachers taught the same things over and over again, so I thought those were the concepts...what I was told was important." Teacher candidates hardly ever mentioned that they played a role in their construction of science knowledge. By large, a science concept was viewed as something learned through instruction other than by personal experience or construction.

With respect to the three most important concepts for elementary students to come to understand, teacher candidates were equally split between the view that there are particular concepts to be understood such as solids, liquids, gases, atoms, and matter on the one hand to the view that elementary students need to understand how, why, and what things can do. Many of the teacher candidates mentioned that ones own natural environment was important to learn but not because it was relevant and important to the individual.

Finally, in this section, the nature of science is seen as something learned in school such as facts, theories, and laws. The nature of science was

not seen as the practice of science with its limitations and construction over time. The nature of science was viewed more as a phenomena to learn that teacher candidates were not apart of. From this science concepts were equally seen as learned in school. There was no distinction between their conception of the nature of science and their conception of a science concept. It is evident that teacher candidates have not developed an understanding of their personal beliefs and values of science and how concept understanding fits into their conceptions of the nature of science itself.

After participating in the methods course, three-fourths of the teacher candidates described the nature of science as the process of discovery. A typical response was, "discovering how things work...investigating and formulating ideas." In general, answers represented views of the actual practice of science itself rather than common school science. Also teacher candidates conceptions revealed that they identified themselves in the process of discovering science phenomena. For example, "I believe the nature of science is someone originally asking why something is the way it is and then trying to change it, improve it, or find out how it works... we should use what we know already to try to make predictions about things are we don't know...science isn't knowing everything, it is using what you know to learn more about what surrounds us...I've realized that a science phenomena may not change but my conception of that phenomena has changed."

In response to the question, How did you develop your conception of the nature of science?, By large, teacher candidates responses indicated a more thorough understanding of their conception attributing this to the process of critical reflection they experience in the methods course. Many teacher candidates said that their conceptions had changed throughout the methods course. Another interesting conception expressed by a few teacher candidates

was that they attributed their conception of the nature of science to a particular course or teacher. For example, "I developed my conceptions of the nature of science during my senior year in high school in my physics class...my physics teacher was a constructivists and taught us about science through inquiry lessons."

A science concept was seen primarily as relative and subject to personal construction of meaning. In general, answers reflected that a science concept is different and always changing. A general response was, "one's own understanding or perception...ideas that have come about through interaction with the world." A typical response was, " A science concept is an idea someone has about a science topic...it may or may not be correct but it is their conception."

With respect to how teacher candidates developed their conception of a science concept, again the overwhelming response was the influence of their own personal reflection and coming to realize that the learner is involved in the process of learning. In general, teacher candidates attributed their conception change to the challenge and reflection they encountered during their experience in the methods course. A typical response was, "by beginning to analyze my conceptions and look beyond the simplicity of just school science...this methods course forced me to reflect upon my own understanding and realizing that I need to focus on the learner and not the teaching."

Few teacher candidates could give examples of the three most important science concepts for elementary students. In general, views centered on the conception that science is always changing and while one concept maybe important to someone it may not be as important to another. Those who did give responses focused on ideas and global conceptions such as systems, interactions.

Finally, in this section, the nature of science is seen as a process of discovery or personal theory building where each person is part of the process of personal discovery. From this science concepts were viewed as relative in that concepts are personally constructed based on one's own belief of the practice of science as a way of knowing. In general, teacher candidates views began to change to view science concepts as global concepts not independent isolated facts. It was evident that teacher candidates had reflected upon their conceptions of the nature of science throughout their experience in the science methods course. While it is tentative to speculate about how this reflection will impact their eventual practice of teaching science; it is encouraging to discover that critical reflection and challenging one's own conception can produce at least a conceptual change in understanding. Another interesting point is that the teacher candidates began to view themselves as learners and not just teachers.

Personal construct of the teaching of science. Under this heading, the following questions were asked: How do you teach a science concept? What led to the development of your conception of science teaching? What way of teaching science would you feel most comfortable using in elementary school and why? What are the teaching qualities of a science teacher? How did you develop your conception of the teaching qualities of a science teacher?

Before participating in the science methods course the majority of the teacher candidates response to the first question was that their conception of teaching science was seen as teaching through lectures, explanations, and demonstrations. A typical response was that, "You introduce the concept, you explain how it became known as a concept and then you demonstrate the concept." Given this typical response few teacher candidates could give other ways of teaching science other than how they were taught and learned science

in previous courses. Not surprisingly, in light of the previous response to the first question, responses indicated that past science classes and instructors had led to their developed conception of teaching science.

With respect to the most comfortable ways of teaching science responses were equally split between teaching the way they were taught on the one hand and teaching using approaches other than lecture. Although teacher candidates mentioned approaches such as hands-on and cooperative groups, they were unsure how to teach this way.

Qualities of a science teacher were seen primarily as someone who is knowledgeable, a good lecturer, and has enthusiasm. This view is perhaps a result of the snapshots of science teachers they have typically encountered throughout school. The conception of teaching qualities was confirmed in the next question where overwhelmingly the responses indicated that past teachers led to their conceptions of good science teaching. A typical response was, "through my college science teachers and through my high school science teachers...also I learned the qualities of science teaching from other subject area teachers. "

Finally, in this section, science teaching was seen as a reflection of past experience with science teachers they had encountered. Many teacher candidates indicated that they wanted to teach using different approaches other than lecture but were unsure how else to teach science any other way. While few mentioned approaches such as hands-on and cooperative learning, they indicated that they had no idea how to teach this way, they just thought it was better than the way they were taught using lecture methods.

After participating in the science methods course, teaching science was seen primarily as finding out what student's conceptions are, challenging their conceptions through discrepant events and designing lessons that are

hands -on/minds-on and to facilitate students personal understanding. A typical response was, "science teachers must be open to change, inquiry, observing...a teacher must allow students to explore, question, and relate science with a full meaning of what science is to them...teachers are learners along with their students."

Overwhelmingly, the majority of teacher candidates attributed their conceptions of science teaching to the experience they encountered by what was modeled in class. Teacher candidates revealed that they were beginning to see themselves as learners and not just teachers. A typical response was, "throughout the semester I have observed, listened, recorded, and had hands-on experiences which have helped me foster my development of science teaching...the methods course has helped me develop into a productive, open-minded, constructivists person." By large, responses indicated that their experiences in the methods course validated their desire to teach in a manner very different from how they were taught.

In response to the question, What way of teaching science would you feel most comfortable using in elementary school and why?, responses indicated teaching in a constructivists manner. A typical response was, "I would feel most comfortable teaching through a constructivists model...the reason for this is because this model places emphasis on the learner as active participants on knowledge conception...this model allows students to grow and discover...by allowing the students to explore and experiment to create understanding and trust." Many teacher candidates stated that they learned more when exposed to hands-on activities that challenged their own conceptions; therefore, they felt comfortable teaching the way they learned. Even through a majority of the teacher candidates mentioned teaching using a constructivists approach using hands-on and cooperative learning, a few still added that they still need to

emphasis vocabulary because they felt unsure about knowing enough about science content.

Qualities of a science teacher were seen primarily as someone who is open to change, inquiry, observing, and fostering individual knowledge construction. A typical response was, "Science teachers must be open to change, inquiry, observing, testing, and using hands-on activities...A science teacher must allow students to explore, question, and relate to science with a full meaning of what science is to them." When asked to explain how they developed their conception of teaching, a majority of teacher candidates mentioned the teaching and learning models they encountered and through self reflection. In general responses indicated views that the methods course fostered their developing conception of teaching science.

Finally, in this section, science teaching was seen as facilitating students personal construction of science. In doing so to provide many experiences for students to explore and examine their own prior conceptions. The role of the teacher was not seen so much as having knowledge of content as it was seen as having the ability to facilitate an open environment that encourages and fosters personal understanding. Teacher candidates began to view themselves as learners along with the students.

Facilitation of science knowledge. Under this heading, the following questions were asked: How do students learn science concepts? How did you develop your conception of how students learn science concepts? How would you assess whether or not a student understands a science concept? What do you think are the most common reasons students have trouble understanding science concepts? What would you do to help students understand a science concept?

Before participating in the science methods course, many responses indicated that students learn science through reading, class, memorizing, repetition, and learning vocabulary. There were a few teacher candidates who mentioned students learn by doing. Although a third of the teaching candidates did not write down an answer or said they had no idea. A typical response was, "students learn science concepts by reading and class talks." In light of their conceptions of how students learn science the majority of responses indicated they developed their conceptions of how students learn by past experience in their science classes. A typical response was, "by how I learned science concepts...memorizing."

When asked the question, How would you assess whether or not a student understands a science concept, teacher candidates saw assessment as merely how students perform on quizzes and tests. For example, a common conception was, "this can be done in many ways through lab results, quizzes, and tests."

By large, teacher candidates assigned the responsibility of students troubled understanding of science concepts on the result of students not studying for quizzes or tests. In other words, teacher candidates saw learning as an automatic transmission or absorption of scientific knowledge. There was no mention that learning is an active process of interpreting information and constructing understanding. It is not surprising then, that many teacher candidates attributed students troubled understanding of science concepts as a lack of transmission of knowledge. Common reasons teacher candidates gave for students troubled understanding was the result of students not taught correctly or not taught enough. For example, "It was the way it was taught...not explained well...science is a little confusing..." Ignored was that learning is an active process of conceptual understanding.

BEST COPY AVAILABLE

Appropriately, teacher candidates when pressed could give few examples of what they would do when a student doesn't understand. A majority of the responses indicated that they would explain the material better to help students understand. However, explaining material better was seen as merely going over material again. Half of the teacher candidates gave no answer as to what to do to help student understand.

Finally, in this section, it is apparent that many teacher candidates saw learning as a process of a transmission of knowledge and assessment as merely what students understand through test and quizzes.

After participating in the science methods course, teacher candidates saw student learning as an active process of constructing meaning and that their role as teachers was to facilitate this process through hands-on experience. A typical response was, "students learn a science concept by doing, observing, questioning, and analyzing...teachers must allow students to do this." Teacher candidates assigned their conception of how students learn through what they experienced and reflected upon in the science methods course and other practical experiences. An overwhelming response was, "...by observing, listening, questioning in this class and through my own practicum experience."

In response to assessment, teacher candidates said they would assess if a student understands a science concept by how well the student can apply the concept in class. Many teacher candidates said that they would use multiple ways to assess depending on what was being assessed.

Overwhelmingly, teacher candidates assigned students lack of understanding to their troubled construction of knowledge and lack of prior knowledge. A general response was that "If a student has trouble understanding a concept, apparently they have had trouble interpreting

information and constructing the new information with what they already know...in this case I would try to find ways to help the students construct understanding...perhaps further challenging their prior conceptions with more experience."

Finally, in this section, facilitation and assessment of student understanding was seen more as an active process of interpreting and constructing knowledge and that it is important to use various strategies to facilitate students understanding of science concepts.

CONCLUSION

The study suggested some promising conclusions:

1. Before participating in the science methods course, few of the teacher candidates appeared to have even considered the question, What is the nature of science? In general, responses represented conceptions of school science such as learning about what exists like matter, living things, and the environment. Teacher candidates did not see themselves as a part of science but something outside themselves to be learned. Teacher candidates did not identify with the actual practice of science itself. After participating in the science methods course, over three-fourths of the teacher candidates saw the nature of science as a process of discovery and personal theory building. Science became something that they are a part of, something they discover by investigating.

2. Before participating in the science methods course, teacher candidates identified a science concept as a fact, term, or a theory to be learned. Conceptual understanding of science was hardly ever mentioned. Teacher candidates did not separate their understanding of the nature of science from their understanding of a science concept. It was evident that teacher candidates did not recognize that their personal

beliefs and values of science contributed to their understanding of science concepts. After participating in the science methods course a majority of the teacher candidates identified a science concept as being relative and subject to personal construction of meaning in which they saw themselves as part of science. In general, teacher candidates conceptions began to change to view science concepts as global concepts not independent isolated facts.

3. Before participating in the science methods course, teacher candidates did not understand that conceptual understanding is the basis of learning and the role of the teacher is to facilitate learning. After participating in the science methods course, teacher candidates recognized that learning is more a construction of individual understanding and that their role should be to facilitate personal construction.

4. Before participating in the science methods course, qualities of a science teacher were seen as being knowledgeable in science and a good communicator; while knowing the learner and facilitating instruction was rarely mentioned. After participating in the science methods course, teacher candidates recognized the necessity to understand the learner and to help foster individual knowledge construction.

5. Before participating in the science methods course, teacher candidates did not generally recognize that knowing the learner is a necessary element to instruction, let alone that students conceptually understand scientific knowledge. Rather, teacher candidates tended to link qualities of science teaching and understanding to a transmission of scientific knowledge. Although transmission was not seen as facilitating students understanding but as transmitting knowledge. After

participating in the science methods course, overwhelmingly, teacher candidates recognized that learning is an active process of constructing knowledge and their role as teachers is to facilitate the learning process.

Discussion

Understanding the substance of science content without understanding its construction and limitations and consequently how to communicate scientific knowledge is an issue that plagues many elementary teacher candidates. For years teacher candidates have been learning the substance of science without learning that science is a way of knowing developed through an individual's beliefs and values and also how to facilitate understanding of science. Teacher candidates are placed in the unenviable position of communicating science knowledge to elementary students without the benefit of a clear understanding of the nature of science. Like many teacher candidates before them, they fall into the same pattern of teaching science as they were taught.

Researchers have recognized the need to better prepare teachers to understand the nature of science and consequently how to teach science. This recognition has led to two assumptions: (1) a teacher's understanding of the nature of science is related to his/her students' conceptions; and (2) a teacher's instructional behaviors and decisions are significantly influenced by his/her conceptions of the nature of science (Lederman, 1992). However, debate still surrounds the issue of whether a teacher's understanding of the nature of science is directly related to their practice of teaching science. Although this study did not address teacher candidates practice of teaching in light of the understanding of the nature of science, it did address whether or not a teacher candidates conceptions or understanding of the nature of science has an influence on their conceptions and understanding of how to teach science.

It is important to mention that researchers have not determined whether possessing valid conceptions of the nature of science does necessarily result in the performance of those teaching approaches which are related to improved students conceptions. It is evident though that teachers cannot teach what they do not understand, and that simply possessing the desired knowledge does not ensure the effective communication to students (MacDonald & Rogan, 1990). While it can be argued that one science methods course is not enough to make permanent changes in teacher candidates conceptions of the nature of science and the teaching of science, nonetheless, conceptions elementary teacher candidates hold concerning the nature of science and science teaching must be illuminated and more importantly challenged.

The focus on teachers conception of the nature of science and the impact such conceptions have on their teaching of science is not only coming from educational researchers but from federal and state agencies such as the National Science Foundation (NSF). Like many other federal and state agencies, NSF is sponsoring a number of programs that focus on promoting better articulation between science and education faculty in the preparation of future science teachers. To this end, many science and education departments are rethinking how they teach science and ultimately how to link what is taught in science courses with what is taught in science methods courses. In order to shed further light on how teachers' conceptions of the nature of science impact their conceptions of teaching science; universities need to look at the big picture of how scientific knowledge is communicated between schools within the university. Science and education faculty need to work together on the issue of preparing scientifically literate teachers.

References

American Association for the Advancement of Science (1989). Project 2061: Science for all Americans. Washington, DC: Author.

American Association for the Advancement of Science (1993). Project 2061: Benchmarks for Science Literacy. Washington, DC: Author.

Anderson, C.W. (1987). Incorporating recent research on learning into the process of science curriculum development. Colorado Springs, CO: Biological Science Curriculum Study.

Baird, J.R., Fensham, P.J., Gunstone, R.F., & White, R. T. (1991). The importance of reflection in improving science teaching and learning. Journal of Research in Science Teaching, 28, 163-182.

Bohm, B. & Peat, F. (1987). Science, order, & creativity. New York: Bantam.

Brickhouse, N.W. (1989). The teaching of the philosophy of science in secondary classrooms: Case studies of teachers' personal theories. International Journal of Science Education, 11(4), 437-449.

Brickhouse, N.W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. Journal of Teacher Education, 41(3), 53-62.

Brooks, J.G., & Brooks, M.G. (1993). In search of understanding the case for constructivists classrooms. Association for Supervision and Curriculum Development. Virginia.

Calderhead, J. (1992). The role of the reflection in the learning to teach. In L. Valli (Ed.), Reflective Teacher Education. Albany, NY: State University of New York Press.

Central Association of Science and Mathematics Teachers. (1907). A consideration of the principles that should determine the courses in

biology in the secondary schools. School Science and Mathematics, 7, 241-247.

Chalmers, A.F. (1988). What is this thing called science? St. Lucia: University of Press.

Cohen, E.G. (1986). Designing Groupwork: Strategies for the Heterogeneous Classroom. New York: Teachers College Press.

Cronin-Jones, L. (1991). Interpretive research methods as a tool for educating science teachers. In J. Gallagher (Ed.), Interpretive research in science education (pp. 217-234). Manhattan, KS: National Association for Research in Science Teaching.

Dewey, J. (1933). How we think, a restatement of the relation of reflective thinking to the educative process. Boston, D.C.: Heath.

Driver, R. & Oldham, V. (1986). A constructivist approach to curriculum development in science. Studies in Science Education, 13, *105-122.*

Driver, R., Asoko, H., Leach, J., Mortimere, M. & Scott, P. (1994). Constructing scientific knowledge in the classroom. Educational Researcher, 5-12.

Duschl, R.A., & Wright, E. (1989). A case study of high school teachers' decision making models for planning and teaching science. Journal of Research in Science Teaching, 26(6), 467-501.

Fosnot, C.T. (1989). Enquiring teachers, enquiring learners: A constructivists approach to teaching. New York: Teachers College Press.

Hazen, R.M., & Trefil, J. (1991) Science Matters. New York: Doubleday.

Hewson, P.W.; Zeichner, K.M.; Tabachnick, B.R.; Blomker, K.B.; & Toolin, R.E. (1992, April). A conceptual change approach to science teacher education at the University of Wisconsin-Madison. Paper presented at the Annual meeting of the American Educational Research Association, San Francisco, CA.

Hodson, D. (1986). Philosophy of science and science education. Journal of Philosophy of Education. 20(2): 215-225.

Johnson, R.T. & Johnson, D.W. (1979). Structuring conflict in science classrooms. Paper presented at the annual meeting of the National Association of Research in Science Teaching, French Link, IN.

Kimball, M.E. (1965). Opinions of scientists and science teachers about science. Unpublished master's thesis. Stanford University, Stanford, CA.

Kimball, M.E. (1986). Understanding the nature of science: A comparison of scientists and science teachers. Journal of Research on Science Teaching, 2(1), 3-6.

Klopfer, L., & Cooley, W. (1961). Test on understanding science, Form W. Princeton, NJ: Educational Testing Service.

Lederman, N.G. (1986). Relating teaching behavior and classroom climate to changes in students' conceptions of the nature of science. Science Education, 70(1), 3-19.

Lederman, N.G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. Journal of Research in Science Teaching, 29(4), 331-359.

Lederman, N.G., & Druger, M. (1985). Classroom factors related to changes in students' conceptions of the nature of science. Journal of Research in Science Teaching, 22(7), 649-662.

Lederman, N.G., & Zeidler, D.L. (1987). Science teachers' conceptions of the nature of science: Do they really influence teacher behavior? Science Education, 71(5), 721-734.

Linn, M.C. & Burbules, N.C. (1993). Construction of Knowledge and Group Learning. In. K. Tobin (Ed.), The Practice of Constructivism in Science Education. (pp. 91-119). New Jersey: Lawrence Erlbaum.

MacDonald, M.A., & Rogan, J.M. (1990). Innovation in South African science education (Part 2): Factors influencing the introduction of instructional change. Science Education, 74(1), 119.

Munby, H. & Russell, T.E. (1989). Education the reflective teacher: An essay review of two books by Donald Schon. Journal of Curriculum Studies. 21: 71-80.

Munby, J. (1982), The place of teachers' beliefs in research on teacher thinking and decision making, and an alternative methodology. Instructional Science, 11, 201-225.

Nadeau, R., & Desautels, J. (1984). Epistemology and the teaching of science: A discussion paper. Ottawa: Science Council of Canada Publications Office.

Raizen, S.A. & Mickelsohn, A. (1994). The future of science in the elementary schools: Education prospective teachers. San Francisco: Jossey-Bass.

Roth, K.L. (1990). Developing meaningful conceptual understandings in science. In B.R. Jones and L. Idol (Eds.). Dimensions of thinking and cognitive instruction. Hillsdale, NJ: Erlbaum.

Rubba, P.A., & Andersen, J. (1978). Development of an instrument to assess secondary school students' understanding of the nature of scientific knowledge. Science Education, 62(4), 449-458.

Russell, T.E. (1993). Learning to teach science: Constructivism, reflection, and learning from experience. In K. Tobin (Ed.), The Practice of Constructivism in Science Education. (pp. 249-258). New Jersey: Lawrence Erlbaum.

DRAFT - do not quote or cite

Rutherford, F.J., & Ahlgren, A. (1990). Science for all Americans. New York: Oxford University Press.

Saunders, H.N. (1955). The teaching of general science in tropical secondary schools. London: Oxford University Press.

Schneps, M. (Producer & Director). (1987). A Private Universe. [Videotape]. Santa Monica, CA: Pyramid Film and Video.

Schon, D.A. (1983). The reflective practitioner: How professionals think in action. New York: Basic Books.

Shapiro, B. (1994). What children bring to light. Teachers College Press, New York.

Shulman, L.S. (1987). Knowledge and teaching foundations of the new reform. In M. Okazawa-Rey, J. Anderson, & R. Traver (Eds.), Teachers teaching & teacher education. Cambridge, Mass.: Harvard Education Review.

Slavin, R.E. (1987). Grouping for instruction in the elementary school. Educational Psychologist. 22: 109-122.

Solomon, J., Duveen, J., Scot, L. & McCarthym, S. (1992). Teaching about the nature of science through history: Action research in the classroom. Journal of Research in Science Teaching. 29(4), 409-421.

Strauss, A.L. (1987). Qualitative Analysis for Social Scientists. New York: Cambridge University Press.

Tobin, K. (1993). Constructivists perspectives on teacher learning. In K. Tobin (Ed.), The Practice of Constructivism in Science Education. Tobin Editor. New Jersey: Lawrence Erlbaum.

Tobin, K. (Ed.). (1993). The practice of constructivism in science education. New Jersey: Lawrence Erlbaum.

Vosniadoe, S. (1991). Designing curricula for conceptual restructuring: Lessons from the study of knowledge acquisition in astronomy. Journal of Curriculum Studies, 23(3): 219-237.

Yager, R.E. (1991). The constructivist's learning model. The Science Teacher. 58: 52-57.

Zeidler, D.L., & Lederman, M.G. (1989). The effects of teachers' language on students' conceptions of the nature of science. Journal of Research in Science Teaching, 26(9), 771-783.

DRAFT - do not quote or cite